



Pesticide Fact Sheet

Name of Chemical:	Furfural
Reason for Issuance:	New Chemical
Date Issued:	September 2006

Description of Chemical

Generic Name:	2-Furancarboxaldehyde
Common Name:	Furfural
Trade Names:	MULTIGUARD™ PROTECT Furfural Technical
EPA Chemical Code:	043301
Chemical Abstracts Service (CAS) Number:	98-01-01
Year of initial registration:	2006
Registration Status:	Conditionally registered
Pesticide Type:	Fumigant – Nematicide/Fungicide
U.S. Producer:	Agriguard Company LLC P.O. Box 630 186 North Avenue East Cranford, N.J. 07016

Use Pattern and Formulations

Furfural is a new pesticidal active ingredient intended for use as a fumigant to control root-infesting plant parasitic nematodes and fungal plant diseases in greenhouse soil used for growing ornamentals and other non-food commodities. The technical formulation (Furfural Technical) contains 99.7% furfural and is for use in formulating end-use products. The end-use product contains 90% furfural in a liquid formulation (Multiguard Protect) and is applied to growing media and/or soils in greenhouses for cut flowers, cut greens, transplants, propagative materials, ornamentals and other non-food/ non-feed commodities.

Table 1: Summary of Directions for Use of Multiguard Protect						
Trade Name Formulation [EPA Reg. Number]	Application Type/Timing and Equipment	Application Rate (lb ai/A)	Maximum Number of Applications per Season	Maximum Seasonal Application Rate (lb ai/A)	PHI (Days)	Use Directions and Limitations
MULTIGUARD™ PROTECT [75753-1]	via broadcast surface spray (handgun), through overhead irrigation, through drip irrigation, or back-pack sprayer/ treatment interval of 14 to 28 days	45	8	360	N/A	The treatment should be watered in after application with 125 gallons of water per 1000 ft ²

Science Findings

Available product chemistry data supporting the use of furfural are summarized below.

Physical/Chemical Structure:

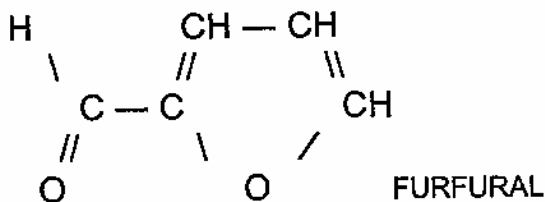


TABLE 2 Physicochemical Properties of the Technical Grade Compound (Furfural).

Parameter	Value
Molecular Weight:	96.1 g/mol
Boiling point:	161.7°C
Density:	1.16g/ml at 20°C
Water solubility (20°C):	7.81 g/100 ml
Solvent solubility (mg/L at 20°C):	alcohol (infinite) ether (infinite) miscible in octanol, acetone, xylene, ethyl acetate, methylene chloride and methanol
Vapor pressure:	2.6 mm Hg (at 20°C)
Dissociation constant (pK _a):	Does not demonstrate a dissociation constant between pKa2 and pKa10.
Octanol/water partition coefficient Log(K _{OW}):	0.35 at 20°C
UV/Visible absorption:	14591.3 cm ² /mole (pH 7) 15324.2 cm ² /mole (pH 1.94) 14584.8 cm ² /mole (pH 10.12)

Tables 3a, 3b, and 3c include toxicity data and summaries published in the open literature. Tables 3a and 3b include the usual acute studies for technical furfural and the end-use product Multiguard Protect. Table 3c summarizes subchronic oral, dermal and inhalation studies as well as chronic, carcinogenicity, developmental and mutagenicity studies.

Table 3a. Acute Toxicity Profile – Multiguard Protect				
Guideline No.	Study Type	MRID(s)	Results	Toxicity Category
870.1100	Acute oral in rats (Mukherjee, 2003)	46028101	LD ₅₀ = >175 mg/kg	II
870.1200	Acute dermal in rats (Joseph, 2003) (Moore, 2004) (Moore, 2004)	46028102 46406102 46406103	LD ₅₀ = 192 mg/kg LD ₅₀ = 2000 mg/kg LD ₅₀ = 2000 mg/kg	I III III Average: II
870.1300	Acute inhalation in rats. (Merkel, 2003)	46106302	LC ₅₀ = 0.54-1.63 mg/L	III
870.2400	Acute eye irritation in rabbits. (Mukherjee, 2003)	46028103	Severe Irritant.	II
870.2500	Acute dermal irritation in rabbits. (Mukherjee, 2003)	46028104	Mild Irritant.	III
	Skin sensitization in Guinea			

870.2600	pigs. (Mukherjee, 2003)	46028105	Non sensitizer.	Neg.
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Table 3 b. Acute Toxicity Profile – Furfural Technical				
Guideline No.	Study Type	MRID(s)	Results	Toxicity Category
870.1100	Acute oral in rats (Rana, 2002)	46011009	LD ₅₀ = >102 mg/kg	II
870.1200	Acute dermal in rats (Joseph, 2003)	46011010	LD ₅₀ = 192 mg/kg	I
870.1300	Acute inhalation in rats. (Merkel, 2003)	46106302	LC ₅₀ = 0.54-1.63 mg/L	III
870.2400	Acute eye irritation in rabbits. (Joseph, 2003)	46011012	Severe. Irritant.	II
870.2500	Acute dermal irritation in rabbits. (Joseph, 2003)	46011013	Slight. Irritant.	IV
870.2600	Skin sensitization in Guinea pigs. (Joseph, 2003)	46011014	Non sensitizer.	Neg.

Table 3 c. Subchronic, Chronic and Other Toxicity Profile for Furfural		
Guideline No./ Study Type	MRID No. (year)/ Classification /Doses	Results
870.3100 90-Day oral toxicity rats	46011015, 1990 Acceptable/ Non-guideline 0, 11, 22, 45, 90, 180 mg/kg/day	NTP 1990 Study (publication). NOAEL = 45 mg/kg/day LOAEL = 90 mg/kg/day based on liver pathology – cytoplasmic vacuolization of hepatocytes.
870.3100 90-Day oral toxicity mice.	46011015, 1990 Acceptable/ Non-guideline 0, 75, 150, 300, 600, 1200 mg/kg/day	NTP 1990 Study (publication). NOAEL < 75 mg/kg/day LOAEL <= 75 mg/kg/day based on relative liver weights.
870.3100 90-Day oral toxicity rats.	46011015, 2001 Summary/ Non-guideline (WHO published review article) 0, 30, 60, 90, 180 mg/kg/day (microencapsulated)	WHO (published review article), Food Additive Series 46 (2001) NOAEL = 60 mg/kg/day LOAEL = 90 mg/kg/day based on liver effects.
870.3150 90-Day oral toxicity dog		No study submitted.
870.3200 28-Day dermal	46465501 Unacceptable/ Guideline	NOAEL =>100 mg/kg/day (HDT). LOAEL => 100 mg/kg/day. Transient effects included drowsiness,

Table 3 c. Subchronic, Chronic and Other Toxicity Profile for Furfural		
Guideline No./ Study Type	MRID No. (year)/ Classification /Doses	Results
toxicity in rats.	0, 25, 50 and 100 mg/kg	dyspnea, clonic convulsion, hyperactivity, tremor, vocalization, generalized effects from exposure to furfural
870.3465 28-Day inhalation toxicity in rats	46426504, -05 Acceptable/Guideline 0, 20, 40, 80, 160, 320, 640, 1280 mg/cu.m.	NTO (Netherlands) 2001 (study publication). LOAEL = < 20 mg/cu.m. (LDT) causing nasal epithelium pathology. NOAEL < 20 mg/cu.m.
870.3700a Prenatal developmental in rats	46147601,1997 primary study: 0, 50, 100, 150 mg/kg/day Acceptable/Guideline w/rangefinder 46629401, 1996 rangefinder: 0, 10, 50, 100,150, 250, 500, 1000 mg/kg/day	Maternal NOAEL = 10 mg/kg/day (from rangefinder) LOAEL = 50 mg/kg/day (from primary) based on clinical signs. Developmental NOAEL => 150 mg/kg/day LOAEL > 150 mg/kg/day , no treatment related effects noted in the primary study, no relevant observations in the rangefinding study.
870.3700b Prenatal developmental in rabbits	46207303, 2004 0, 25, 75, 225 mg/kg/day 46207302, 2003 (rangefinder) 0, 25, 50, 100, 150, 300 mg/kg/day	Maternal NOAEL = 225 mg/kg/day LOAEL = 300 mg/kg/day based on decreased bw, bwg - primary study combined with rangefinder study data Developmental NOAEL = 225 mg/kg/day LOAEL = 300 mg/kg/day based on decreased fetal bw - primary study combined with rangefinder study data
870.3800 Reproduction and fertility effects		No study available.
870.4100a Chronic toxicity Rats	46011016, 1990 Acceptable/ Non-guideline . 0, 30, or 60 mg/kg/day	NTP 1990 Study (publication). NOAEL = 30 mg/kg/day LOAEL = 60 mg/kg/day based on liver effects.
870.4100a Chronic toxicity – mice	46011016, 1990 Acceptable/ Non-guideline . 0, 50, 100, or 175 mg/kg/day	NTP 1990 Study (publication) NOAEL => 175 mg/kg/day LOAEL > 175 mg/kg/day
870.4100b Chronic toxicity dog		No study submitted.
870.4200 Carcinogenicity rat.	46011016, 1990 Acceptable/ Non-guideline 0, 30, 60 mg/kg/day	NTP 1990 Study (publication). NOAEL = 30 mg/kg/day LOAEL = 60 mg/kg/day based on liver effects. no evidence of carcinogenicity at dose levels tested
870.4300 Carcinogenicity	46011016, 1990 Acceptable/ Non-guideline	NTP 1990 Study (publication) NOAEL => 175 mg/kg/day

Table 3 c. Subchronic, Chronic and Other Toxicity Profile for Furfural		
Guideline No./ Study Type	MRID No. (year)/ Classification /Doses	Results
mouse.	0, 50, 100, 175 mg/kg/day	LOAEL > 175 mg/kg/day no evidence of carcinogenicity at dose levels tested
Gene Mutation 870.5100	46011017; 1999 Acceptable/Guideline	Negative for bacterial reverse mutation assay
Gene Mutation 870.5100	46011018; 2003 Acceptable/Non-guideline	Negative for <i>in vivo</i> gene mutation bacterial gene incorporation into genome of transgenic mice
CA/SCE 870.5375, 870.5385, 870.5900, 870.5915	46011019; 2003 (compilation of 7 reports)	Negative and Acceptable/Guideline: Reverse Gene Mutation, In vitro mammalian gene mutation and chromosomal aberrations , In vivo Chromosomal Aberrations, SCE, Gene Mutation – Drosophila Unacceptable/Guideline – Expert Panel Report, SCE in human Lymphocytes, in vitro cytogenetic assays
UDS 870.5500, 870..5560	46011020; 2003 (compilation of 9 reports)	Negative for DNA damage/repair, rec-assay, UDS in rat hepatocytes – Acceptable/Guideline DNA damage, summary reports - Unacceptable
870.7485 Metabolism and pharmacokinetics		No study submitted.
870.7600 Dermal penetration		No study submitted.

Non-guideline = studies either from the open literature, studies not meeting guideline requirements, but contain useful information or range-finding studies

Hazard Considerations

The acute toxicity profile for furfural ranges from highly toxic to relatively non-toxic (from Toxicity Category of I to IV). Technical furfural has a pungent odor smelling like almonds. It is irritating to skin, mucous membranes and the respiratory system. Single- and repeated dose animal toxicity studies in the open literature, using various routes and animal species, give evidence of adverse effects involving most physiological systems including respiratory system, liver and kidney, blood and bone marrow as well as adverse effects to the nervous system.

Studies in humans and animals show that furfural is readily absorbed and is excreted in the urine. The American Conference of Governmental Industrial Hygienist's (ACGIH) occupational standard for furfural, or Threshold Limit Value (TLV) is 2 ppm with a "Skin" notation for concerns for vapor irritation of skin and mucous membranes. The human data referred to above (dermal absorption studies) fall outside the scope of the prohibition on use of human data. The Agency has not classified the carcinogenic potential of furfural at this time, however, a National

Toxicity Program (NTP) carcinogenicity study in rats and mice does not indicate a potential for carcinogenicity.

The toxicology dataset includes acute toxicity studies and studies published in the open literature including a subchronic oral toxicity study in rats and mice, a chronic oral toxicity study in rats and mice, two oral developmental studies, one in rats and the other in rabbits, a 28-day dermal study in rats, 28-day inhalation study in rats, as well as a number of review articles from regulatory (primarily European) agencies. Based on the indoor (greenhouse), non-food use pattern, the dermal and inhalation routes appear to be the major routes of exposure. Consequently, the current data base review focuses on these routes to assess potential hazards for worker and bystander exposures.

Food Quality Protection Act Considerations

Furfural is a new active ingredient for use in production of greenhouse ornamentals which is considered to be a 'non-food use' and is not subject to the amendments to the Federal Food, Drug, and Cosmetic Act (FFDCA) promulgated under the Food Quality Protection Act (FQPA) of 1996, and an aggregate risk assessment is not required.

Hazard Identification and Toxicity Endpoint Selection

Based on the proposed use patterns (greenhouse), the primary exposure pathways for furfural are the inhalation and dermal routes. Since furfural is considered a non-food use active ingredient and there are no residential uses, oral risk assessments (dietary and incidental oral) have not been conducted at this time. However, should use patterns change in the future to include food uses and/or residential uses, the Agency may conduct these risk assessments.

Toxicological Endpoints

Table 4: Summary of inhalation Toxicological Doses and Endpoints Selected Using the RfC Methodology												
Relevant Study		LOAEL (mg/m ³)	NOAEL (mg/m ³)	Da	Dh	Wa	Wh	RGDR *	HEC (mg/m ³)	inter	Intra	UF [§]
HEC Array for Non-Occupational Risk Assessment												
<i>Acute Exposure</i>												
28-Day Inhalation Study - RATS	Extrathoracic region (6hr exp.)	20	N.A.	6	24	1	1	0.115	0.58	3	10	10
	Extrathoracic region (3hr exp.)	160	N.A.	3	24	1	1	0.115	2.30	3	10	10
<i>Short-, Intermediate-, and Long-term Exposure</i>												
28-Day Inhalation Study - RATS	Extrathoracic region (6hr exp.)	20	N.A.	6	24	5	7	0.115	0.41	3	10	10
	Extrathoracic region (3hr exp.)	160	N.A.	3	24	5	7	0.115	1.64	3	10	10
HEC Array for Occupational Risk Assessment												
<i>Acute Exposure</i>												
28-Day Inhalation Study - RATS	Extrathoracic region (6hr exp.)	20	N.A.	6	8	1	1	0.115	1.73	3	10	10
	Extrathoracic region (3hr exp.)	160	N.A.	3	8	1	1	0.115	6.90	3	10	10
<i>Short-, Intermediate-, and Long-term Exposure</i>												
28-Day Inhalation Study - RATS	Extrathoracic region (6hr exp.)	20	N.A.	6	8	5	5	0.115	1.73	3	10	10
	Extrathoracic region (3hr exp.)	160	N.A.	3	8	5	5	0.115	6.90	3	10	10

[§] 10X UF retained for LOAEL to NOAEL extrapolation.

- Input parameters for the derivation of Regional Gas Dose Ratios (RGDR) were obtained from “Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry” (US EPA, 1994) Tables 4-4, 4-5, and 4-6.

Table 5. Summary of Toxicological Doses and Endpoints for Chemical for Use in Human Risk Assessments

Exposure Scenario	Dose Used in Risk Assessment, UF	FQPA SF* and Level of Concern for Risk Assessment	Study and Toxicological Effects
Dermal Short-Term (1 - 30 days)	NOAEL = 10 mg/kg/day, UF 100	N/A	Prenatal developmental in rats; Maternal LOAEL = 50 mg/kg/day based on clinical signs.
Dermal Intermediate-Term (1 - 6 months)	NOAEL = 10 mg/kg/day, UF 100	N/A	Prenatal developmental in rats; Maternal LOAEL = 50 mg/kg/day based on clinical signs.
Dermal Long-Term (> 6 months)	NOAEL = 10 mg/kg/day, UF 1000 (extra 10X for extrapolation for duration)	N/A	Prenatal developmental in rats; Maternal LOAEL = 50 mg/kg/day based on clinical signs.
Inhalation All Durations	Refer to Table 4 for the HEC Array for Bystander and Occupational Exposure	N/A	28-day inhalation toxicity in rats; LOAEL = 20 mg/ cu.m. nasal epithelial pathology seen throughout all of the treated animal groups, no NOAEL was identified

UF = uncertainty factor, FQPA SF = FQPA safety factor, NOAEL = no observed adverse effect level, LOAEL = lowest observed adverse effect level, PAD = population adjusted dose (a = acute, c = chronic) RfD = reference dose, MOE = margin of exposure, LOC = level of concern, NA = Not Applicable

Exposure Assessment

Residential/Bystander Exposure Estimates

Furfural is not registered for residential uses. However, residential/bystander exposure is possible from drift of furfural vapors associated with the greenhouse use. A screening level bystander exposure assessment was conducted using the only available data, a laboratory soil volatility study, which raise many uncertainties when used for the purpose of assessing bystander exposure.

These laboratory data were used as inputs to EPA's Industrial Source Complex: Short-Term Model (ISCST3) to estimate furfural concentrations outside the greenhouse after a furfural application. The inhalation LOC for bystanders is an MOE of 300 or greater, below which indicate risks of concern. The modeling results indicate that, for bystanders, a distance of 30 meters downwind may be necessary to achieve an MOE of 300 for small greenhouses, and a distance of 100 meters may be required for large greenhouses. Please note that there is low confidence in these estimates because they are based on data that, in addition to other significant limitations, were not generated under field conditions.

Dietary Exposure Estimates

Furfural is registered for use on greenhouse ornamentals only. Therefore, a dietary assessment is not necessary. Additionally this use pattern is considered to have minimal potential for causing drinking water contamination. A dietary exposure assessment for drinking water was not conducted.

Aggregate Exposure Scenarios and Risk Conclusions

Furfural use in greenhouses on ornamentals is considered a non-food use and therefore an aggregate risk assessment is not required under the FQPA.

Occupational Exposure Estimates

Dermal occupational handler exposures were estimated using the Pesticide Handlers Exposure Database (PHED) Surrogate Exposure Guide (revised August, 1998). For some of the occupational handler scenarios that reflect baseline clothing, dermal occupational handler risks are of concern (i.e., the MOEs do not reach 100). However, when gloves are added, all handler scenarios have MOEs of 100 or greater, and therefore, are not of concern.

A non-guideline dislodgeable foliar residue (DFR) study was used to assess potential dermal exposure to postapplication workers. The postapplication exposure assessment indicates that dermal occupational risks are of concern (i.e., the MOEs are less than 100) on day 0, and up to 9 days following application, depending on the scenario. Acceptable MOEs (<100) are achieved using restricted entry intervals (REIs) of 12 hours for containerized ornamentals, and 9 days for cut flowers.

Inhalation handler risks for furfural were not assessed using PHED because furfural is much more volatile (2 mm Hg at 20 °C) than the pesticides that are incorporated into PHED. As a result, inhalation risks would be underestimated if PHED data were used to assess inhalation handler exposures. The inhalation postapplication exposures and risks can be considered a surrogate to represent inhalation handler exposures and risks.

To assess potential inhalation exposure to postapplication workers, the agency utilized EPA's Multi-Chamber Concentration and Exposure Model (MCCEM) to estimate furfural concentrations inside the greenhouse after a furfural application. For all greenhouse postapplication exposure scenarios, inhalation postapplication occupational risks are of concern (i.e., the MOEs are less than 300) on day 0 using worst-case air exchange rates. Postapplication inhalation MOEs do not reach 300 until the air exchange rates are increased to 65 per hour (based on 8-hour average) or 90 per hour (based on 1-hour average).

Environmental Fate and Ecological Effects

Environmental Fate Data Requirements:

A hydrolysis study (Guideline 161-1) was reviewed and classified as Acceptable. In this study, furfural appeared to be stable in buffered solutions of pHs 5, 7 and 9.

An aerobic soil metabolism study (Guideline 162-1) and additional data were submitted by the registrant. The study is classified as supplemental. The available data are sufficient to support the indoor and greenhouse uses. Furfural appears to degrade rapidly in four sandy loams with observed half-lives of <1 day. Studies performed with archived samples (stored for a period of 15 months at 20⁰ C) indicate that the major transformation product is 2-furoic acid.

A batch equilibrium – adsorption/desorption study (Guideline 163-1) and additional data was classified as supplemental. The data available are sufficient to support the indoor and greenhouse use. It appears that furfural residues are highly mobile in three sandy loam soils ($K_{F,OC}$ range 52.2-56.9) and has low mobility in a Bog sand with a very low organic carbon content ($K_{F,OC} = 607.3:OC = 0.06\%$).

Ecological Effects Data Requirements:

Since greenhouse use is strictly an indoor use, an ecological risk assessment was not performed.. However, avian acute oral toxicity, freshwater fish acute toxicity, and freshwater aquatic invertebrate acute toxicity studies were submitted to support the manufacturing use product. These data are intended to support labeling in the event of spills.

The registrant has submitted a variety of acute toxicity data, in part to also support future outdoor use. Those data relevant to indoor use are summarized below.

Avian acute oral toxicity (Guideline 850.2100). Mallard ducks and Japanese quail acute oral toxicity studies indicate that furfural is considered moderately toxic to mallard, with an LD50 of 360.5 mg/kg in an Acceptable study and that furfural is considered moderately toxic to the Japanese quail with an LD50 of 278.5 mg/kg in a Supplemental study.

Acute fish toxicity (Guideline 850-1075). Bluegill sunfish and rainbow trout studies indicate that furfural is considered moderately toxic to the rainbow trout with an LC50 of 3.06 ppm in a Supplemental study and that furfural is considered moderately toxic to the bluegill sunfish with an LC50 of 5.8 ppm in an Acceptable study.

Acute aquatic invertebrate toxicity (Guideline 850-1010). A *Daphnia magna* study indicates that furfural is considered slightly toxic to *D. magna* with an LC/EC50 of 20.4 ppm in an Acceptable study.

Data Gaps

An acceptable 28-day dermal toxicity study

A guideline 28- or 90-day inhalation study

A field/greenhouse volatility study for each major application method (i.e., groundboom, overhead spray, overhead irrigation, and drip irrigation) that measures the flux inside the greenhouse, as well as the outside perimeter. (A protocol for this study has recently been submitted and reviewed; several changes are necessary for the protocol to be acceptable.)

A dislodgeable foliar residue study (or soil residue transfer data, if more applicable) to assess postapplication exposure for tasks associated with greenhouse ornamentals. (A protocol for this study has recently been submitted and reviewed; it was found to be acceptable, with recommendations for minor changes.)

Risk Mitigation Measures

The end use product label for Multiguard Protect was revised to contain the following labeling:

1. The greenhouse air exchange rate was increased from 12 air changes per hour (ACH) to 90 ACH during mixing/loading and application, and for at least 48 hours following application.
2. Buffer zones were added (90 ft. buffer zones for greenhouses < 5,000 sq. ft, and 300 ft. buffer zones for greenhouses > 50,000 sq. ft.).
3. Labeling requirement that owner/operator of greenhouses own/have control over all land which falls within the buffer zones.
4. In addition to posting of greenhouses as required by the Worker Protection Standard, a labeling requirement that buffer zones must be posted at all points of entry into the buffer zone area.
5. A restricted entry interval (REI) of 12 hours is required for entry into areas of containerized ornamentals and an REI of 9 days for areas containing cut flowers.

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DISCLAIMER: The information presented in this Pesticide Fact Sheet is for informational purposes only and may not be used to fulfill data requirements for pesticide registration and reregistration.

APPENDIX I:

GLOSSARY OF TERMS AND ABBREVIATIONS

ADNT **Acute delayed neurotoxicity**

a.i.	Active Ingredient
aPAD	Acute Population Adjusted Dose
ARI	Aggregate Risk Index
BCF	Bioconcentration Factor
CAS	Chemical Abstracts Service
ChE	Cholinesterase
ChEI	Cholinesterase inhibition
cPAD	Chronic Population Adjusted Dose
%CT	Percent crop treated
DAT	Days after treatment
DEEM-FCID	Dietary Exposure Evaluation Model - Food Consumption Intake Database
DNA	Deoxyribonucleic acid
DNT	Developmental neurotoxicity
DIT	Developmental immunotoxicity
DWLOC	Drinking Water Level of Comparison.
EC	Emulsifiable Concentrate Formulation
EEC	Estimated Environmental Concentration. The estimated pesticide concentration in an environment, such as a terrestrial ecosystem.
EPA	U.S. Environmental Protection Agency
FQPA	Food Quality Protection Act
GLC	Gas Liquid Chromatography
GLN	Guideline Number
LC₅₀	Median Lethal Concentration. A statistically derived concentration of a substance that can be expected to cause death in 50% of test animals. It is usually expressed as the weight of substance per weight or volume of water, air or feed, e.g., mg/l, mg/kg or ppm.
LD₅₀	Median Lethal Dose. A statistically derived single dose that can be expected to cause death in 50% of the test animals when administered by the route indicated (oral, dermal, inhalation). It is expressed as a weight of substance per unit weight of animal, e.g., mg/kg.
LOAEL	Lowest Observed Adverse Effect Level
LOAEC	Lowest Observed Adverse Effect Concentration
LOC	Level of Concern
LOD	Limit of Detection
LOQ	Limit of quantitation
mg/kg/day	Milligram Per Kilogram Per Day
mg/L	Milligrams Per Liter
MOE	Margin of Exposure
MRID	Master Record Identification (number), EPA's system of recording and tracking studies submitted
MTD	Maximum tolerated dose
NA	Not Applicable
NOEC	No Observable Effect Concentration
NOEL	No Observed Effect Level

NOAEL	No Observed Adverse Effect Level
NOAEC	No Observed Adverse Effect Concentration
NPDES	National Pollutant Discharge Elimination System
OP	Organophosphate
OPP	EPA Office of Pesticide Programs
OPPTS	EPA Office of Prevention, Pesticides and Toxic Substances
PAD	Population Adjusted Dose
PAG	Pesticide Assessment Guideline
PAM	Pesticide Analytical Method
PHED	Pesticide Handler's Exposure Data
PHI	Preharvest Interval
ppb	Parts Per Billion
PPE	Personal Protective Equipment
ppm	Parts Per Million
PRZM/	
EXAMS	Tier II Surface Water Computer Model
RAC	Raw Agriculture Commodity
RBC	Red Blood Cell
RED	Reregistration Eligibility Decision
REI	Restricted Entry Interval
RfD	Reference Dose
SCI-GROW	Tier I Ground Water Computer Model
SF	Safety Factor
TGAI	Technical Grade Active Ingredient
UF	Uncertainty Factor
µg	micrograms
µg/L	Micrograms Per Liter
µL/g	Microliter per gram
USDA	United States Department of Agriculture
WPS	Worker Protection Standard

Appendix II

Citations Considered to be Part of the Data Base Supporting the Registration of Furfural

MRID: 38152

Citation: McMahon, R.E.; Cline, J.C.; Thompson, C.Z. (1979) Assay of 855 test chemicals in ten tester strains using a new modification of the Ames test for bacterial mutagens. Cancer Research 39 (?/Mar):682-692. (Also~In~unpublished submission received on unknown date under 1471-96; submitted by Elanco Products Co., Div. of Eli Lilly and Co., Indianapolis, Ind.; CDL:242442-E)

MRID: 63152

Citation: Sanderson, D.M. (1968?) Toxicology of the Acaricide NC 5016: Potentiation Studies on NC 5016: Report No. 7. (Unpublished study received May 10, 1970 under 0F0897; prepared by Fisons, Ltd., England, submitted by Fisons Corp., Agricultural Chemicals Div., Bedford, Mass.; CDL:091548-D)

MRID: 85292

Citation: Quaker Oats Company (1957) Physiological Data on QO Furfural. (Unpublished study received Oct 5, 1967 under unknown admin. no.; CDL:110733-A)

MRID: 40701200

Citation: Great Lakes Chemical Corp. (1988) Submission of Data To Support Registration of CN-1291: Product Chemistry and Toxicology Data. Transmittal of 4 studies.

MRID: 40701201

Citation: Handy, R. (1988) CN 1291: Product Chemistry Data: Product Identity and Composition. Unpublished study prepared by Great Lakes Chemical Corp. 4 p.

MRID: 40701202

Citation: Handy, R. (1988?) CN-1291: Product Chemistry Data: Analysis and Certification of Product Ingredients. Unpublished study prepared by Great Lakes Chemical Corp. 15 p.

MRID: 40701203

Citation: Handy, R. (1988?) CN-1291 Product Chemistry Data: Physical and Chemical Characteristics. Unpublished study prepared by Great Lakes Chemical Corp. 4 p.

MRID: 40701204

Citation: Jagannath, D. (1988) Mutagenicity Test on CN-1291 in the Ames Salmonella/Microsome Reverse Mutation Assay: Project ID: 10292-0-401. Unpublished study prepared by Hazleton Laboratories America, Inc. 31 p.

MRID: 46009300

Citation: Agriguard Company LLC (2003) Submission of Product Chemistry, Environmental Fate, Exposure and Toxicity Data in Support of the Application for Registration of Multiguard Protect. Transmittal of 6 Studies.

MRID: 46009301

Citation: Eickhoff, J. (2003) Multiguard Protect - Product Identity, Composition, and Analysis. Project Number: MG/PROTECT/2003/NFG/, 13256, P803. Unpublished study prepared by Toxcel LLC and Product Safety Labs. 95 p.

MRID: 46009302

Citation: Eickhoff, J. (2003) Multiguard Protect - Physical and Chemical Characteristics. Project Number: MG/PROTECT/2003/NFG/, /PROTECT/2003/NFG/03, 13258. Unpublished study prepared by: Toxcel LLC and Product Safety Labs. 78 p.

MRID: 46009303

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MRID: 46009304

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MRID: 46009307

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MRID: 46011003

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MRID: 46011004

Citation: McLaughlin, S. (2003) (Carbon 14) Furfural- Determination of pH Dependent Hydrolysis. Project Number: 13782.6101. Unpublished study prepared by Springborn Smithers Laboratories. 80 p.

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Citation: McLaughlin, S. (2003) (Carbon 14)Furfural - Determination of Photodegradation in an Aqueous Solution: Interim Report. Project Number: 13782/6103. Unpublished study prepared by Springborn Smithers Laboratories. 116 p.

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MRID: 46011012

Citation: Joseph, S. (2003) Acute Eye Irritation Study of Furfural in Rabbits. Project Number: 3952. Unpublished study prepared by Jai Research Foundation. 38 p.

MRID: 46011013

Citation: Joseph, S. (2003) Acute Dermal Irritation Study of Furfural in Rabbits. Project

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MRID: 46011014

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MRID: 46011019

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MRID: 46011020

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MRID: 46028100

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Citation: Mukherjee, A. (2003) Acute Oral Toxicity Study of Multiguard Protect in Rats. Project Number: 4227. Unpublished study prepared by Jai Research Foundation. 39 p.

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Citation: Mukherjee, A. (2003) Acute Dermal Toxicity Study of Multiguard Protect in Rats. Project Number: 4228. Unpublished study prepared by Jai Research Foundation. 43 p.

MRID: 46028103

Citation: Mukherjee, A. (2003) Acute Eye Irritation Study of Multiguard Protect in Rabbits. Project Number: 4230. Unpublished study prepared by Jai Research Foundation. 39 p.

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Citation: Mukherjee, A. (2003) Acute Dermal Irritation Study of Multiguard Protect in Rabbits. Project Number: 4229. Unpublished study prepared by Jai Research Foundation. 34 p.

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MRID: 46106300

Citation: Agriguard Company LLC (2003) Submission of Environmental Fate and Toxicity Data in Support of the Application for Registration of Furfural Technical. Transmittal of 2 Studies.

MRID: 46106301

Citation: Gledhill, W. (2003) (Carbon 14) Multiguard Protect - Volatility from Soil Under Laboratory Conditions. Project Number: 13782/6109. Unpublished study prepared by Springborn Smithers Laboratories. 82 p.

MRID: 46106302

Citation: Merkel, D. (2003) Acute Inhalation Toxicity Study in Rats: Furfural Technical. Project Number: 13613, P330/ILL. Unpublished study prepared by Product Safety Labs, Food Products Laboratory and Silliker Laboratories of New Jersey, Inc. 44 p.

MRID: 46109500

Citation: Agriguard Company, LLC (2003) Submission of Toxicity Data in Support of the Application for Registration of Multiguard Protect. Transmittal of 1 Study.

MRID: 46109501

Citation: Merkel, D. (2003) Acute Inhalation Toxicity Study in Rats: Multiguard Protect. Project Number: 13686, P330/ILL2. Unpublished study prepared by Product Safety Labs, Food Products Laboratory and Silliker Laboratories of New Jersey, Inc. 38 p.

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Citation: Agriguard Company LLC (2003) Submission of Toxicity Data in Support of the Application for Registration of Furfural Technical. Transmittal of 1 Study.

MRID: 46147601

Citation: Nemec, M. (1997) A Developmental Toxicity Study of Furfural in Rats: Final Report. Project Number: WIL/12378. Unpublished study prepared by WIL Research Laboratories, Inc. 346 p.

MRID: 46207300

Citation: Agriguard Company LLC (2004) Submission of Toxicity and Risk Data in Support of the Application for Registration of Furfural Technical. Transmittal of 4 Studies.

MRID: 46207301

Citation: Palmer, S.; Kendall, T.; Krueger, H. (2004) Furfural: A 96-Hour Flow-Through Acute Toxicity Test with the Bluegill (*Lepomis macrochirus*): Final Report. Project Number: 566A/101, 566/1002/BLU/96H2/OECD/OPPTS/100P/604. Unpublished study prepared by Wildlife International, Ltd. 54 p.

MRID: 46207302

Citation: Knapp, J. (2004) A Dose Range-Finding Developmental Toxicity Study of Technical Grade Furfural in Rabbits: Final Report. Project Number: WIL/477001. Unpublished study prepared by WIL Research Laboratories, Inc. 354 p.

MRID: 46207303

Citation: Knapp, J. (2004) A Prenatal Developmental Toxicity Study of Furfural in Rabbits: Final Report. Project Number: WIL/477002. Unpublished study prepared by WIL Research Laboratories, Inc. 485 p.

MRID: 46207304

Citation: Katz, A.; Eickhoff, J. (2004) WHO Safety Evaluations of Furfural. Project Number: FURFURAL/2004/1. Unpublished study prepared by Toxcel LLC. 108 p.

MRID: 46331500

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MRID: 46331505

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MRID: 46331506

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MRID: 46331507

Citation: Whitmyre, G. (2004) Exposure and Risk Assessment for Indoor Non-Residential Use of Multiguard Protect on Non-Food Crops: (Furfural). Project Number: 04/RS59, NTP/TR/382. Unpublished study prepared by Risksciences.Com, L.L.C. and Toxcel LLC. 344 p.

MRID: 46343000

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MRID: 46343001

Citation: Desai, Y. (2004) Acute Immobilisation Study of Furfural in *Daphnia magna*. Project Number: 4601. Unpublished study prepared by Jai Research Foundation. 49 p.

MRID: 46343002

Citation: Desai, Y. (2004) Acute Toxicity Study of Furfural In Rainbow Trout, *Oncorhynchus mykiss*. Project Number: 4600. Unpublished study prepared by Jai Research Foundation. 44 p.

MRID: 46343003

Citation: Kumar, A. (2004) Acute Oral Toxicity (LD50) Study of Furfural in Japanese Quail. Project Number: 4604. Unpublished study prepared by Jai Research Foundation. 48 p.

MRID: 46343004

Citation: Kumar, A. (2004) Acute Oral Toxicity (LD50) Study of Furfural in Mallard Ducks. Project Number: 4605. Unpublished study prepared by Jai Research Foundation. 46 p.

MRID: 46406100

Citation: Agriguard Company, LLC (2004) Submission of Product Chemistry and Toxicity Data in Support of the Application for Registration of Multiguard Protect. Transmittal of 3 Studies.

MRID: 46406101

Citation: Wo, C. (2004) Two Year Storage Stability and Corrosion Characteristics - 12 Month Interim Report: Multiguard Protect. Project Number: 13257, P814. Unpublished study prepared by Product Safety Labs. 43 p.

MRID: 46406102

Citation: Moore, G. (2004) Acute Dermal Toxicity Study in Rats: Furfural. Project Number: P322/TOX, 15621. Unpublished study prepared by Product Safety Labs. 28 p.

MRID: 46406103

Citation: Moore, G. (2004) Acute Dermal Toxicity Study in Rats - Defined LD50: MP-12. Project Number: P322/KATZ, 15139. Unpublished study prepared by Product Safety Labs. 31 p.

MRID: 46424100

Citation: Agriguard Company, LLC. (2004) Submission of Product Chemistry and Toxicity Data in Support of the Application for Registration of Multiguard Protect. Transmittal of 2 Studies.

MRID: 46424101

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Citation: Wo, C. (2004) Characterization of Active: Multiguard Protect. Project Number: P803, 16079. Unpublished study prepared by Product Safety Labs. 21 p.

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MRID: 46426501

Citation: McLaughlin, S. (2004) [14-C]Furfural - Determination of Photodegradation in an Aqueous Solution and Separation, Isolation and Identification of Photoproducts Present at Less Than or Equal to 10% of Applied Dose. Project Number: 13782/6103. Unpublished study prepared by Springborn Smithers Laboratories. 198 p.

MRID: 46426502

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Citation: Gledhill, W. (2004) [14-C]Furfural - Plant Uptake and Translocation Test. Project Number: 13782/6111. Unpublished study prepared by Springborn Smithers Laboratories. 119 p.

MRID: 46426504

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MRID: 46426505

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MRID: 46426507

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MRID: 46426508

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MRID: 46426509

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MRID: 46426511

Citation: Whitmyre, G. (2004) Assessment of Worker and Residential Exposures to Furfural Associated with Use of Multiguard Protect on Turf. Project Number: TC/04/RS64. Unpublished study prepared by Risksciences L.L.C. 59 p.

MRID: 46426512

Citation: Hlinka, D. (2004) Air Dispersion Modeling Analysis for Furfural Emissions from Golf Courses, Turf Farms and Residential Turf Treatments of Multiguard Protect. Unpublished study prepared by Sullivan Environmental Consulting. 12 p.

MRID: 46465500

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MRID: 46465501

Citation: Bhoite, P. (2004) Repeated Dose 28-Day Dermal Toxicity Study of Furfural in Rats Followed by a 4-Week Recovery Period. Project Number: 4700. Unpublished study prepared by Jai Research Foundation. 325 p.

MRID: 46510600

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MRID: 46510602

Citation: Kovacs, M. (2005) Supporting Data from "Aerobic Soil Metabolism Study of Furfural" (MRID# 46011007) Referenced as Attachments A through I in Volume 1: Response to EFED/ERD #4 in July 14, 2004 Comments in DER (DP Barcode D295312), Completed March 29, 2005. Project Number: 13782/6100. Unpublished study prepared by Toxcel LLC. 105 p.

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MRID: 46523601

Citation: Kovacs, M. (2005) Response to EFED/ERB#4 6/8/2004 Comments in DER (DP Barcode D295312) on the Phototransformation in Water of Furfural. Unpublished study prepared by Toxcel LLC. 6 p.

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Citation: Agriguard Company LLC Submission of Fate Data in Support of the Application for Registration of Furfural Technical. Transmittal of 1 Study.

MRID: 46523701

Citation: Kovacs, M. (2005) Response to EFED/ERB #4 July 14, 2004 Comments in DER (DP Barcode D295312) on the Aerobic Biotransformation of Furfural in Soil. Unpublished study prepared by Toxcel LLC. 19 p.

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MRID: 46523801

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MRID: 46523900

Citation: Agriguard Company LLC (2005) Submission of Fate Data in Support of the Application for Registration of Furfural Technical. Transmittal of 1 Study.

MRID: 46523901

Citation: Kovacs, M. (2005) Response to EFED/ERB#4 6/15/2004 Comments in DER (DP Barcode D298145) on the Laboratory Volatility of Furfural from Soil. Unpublished

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MRID: 46531400

Citation: Agriguard Co., LLC. (2005) Submission of Product Chemistry Data in Support of the Application for Registration of Multiguard Project. Transmittal of 1 Study.

MRID: 46531401

Citation: Wo, C. (2005) Two Year Storage Stability and Corrosion Characteristics: Multiguard Protect. Project Number: P814, 13257. Unpublished study prepared by Product Safety Laboratories. 48 p.

MRID: 46629400

Citation: Agriguard Company LLC (2005) Submission of Toxicity Data in Support of the Application for Registration of Furfural Technical. Transmittal of 1 Study.

MRID: 46629401

Citation: Nemec, M. (1997) A Dose Range-Finding Developmental Toxicity Study of Furfural in Rats. Project Number: WIL/12377. Unpublished study prepared by WIL Research Laboratories, Inc. 416 p.

MRID: 46701000

Citation: Agriguard Co., LLC (2005) Submission of Toxicity Data in Support of the Application for Registration of Furfural Technical. Transmittal of 1 Study.

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MRID: 46752301

Citation: Kovacs, M.; Katz, A.; Whitmyre, G. (2006) Response to HED/EFED Risk Assessment Attached to EPA Letter (M. Waller) Dated November 4, 2005: (Furfural Technical). Unpublished study prepared by Toxcel, LLC. 43 p.

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Citation: Agriguard Co., LLC (2006) Submission of Environmental Fate Data in Support of the Application for Registration of Fufural Technical. Transmittal of 1 Study.

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MRID: 46764800

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MRID: 46764801

Citation: Somera, S. (2006) Dislodgeable Foliar Residue Study: Multiguard Protect. Unpublished study prepared by Illovo Sugar Ltd. 44 p.

MRID: 46809700

Citation: Agriguard Company, LLC (2006) Submission of Residue Data in Support of the Application for Registrations of Furfural Technical and Multiguard Protect. Transmittal of 1 Study.

MRID: 46809701

Citation: Burger, G. (2006) Dislodgeable Foliar Residue Study for MultiGuard Protect. Unpublished study prepared by Illovo Sugar Ltd. 49 p.